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THE LIFE OF LORD KELVIN.

The Life of William Thomson, Baron Kelvin of Largs. By Silvanus P. Thompson. Vol. i., pp. xx+584; vol. ii., pp. xi+585-1297. (London: Macmillan and Co., Ltd., 1910.) Two vols. Price 30*s*. net.

THE task of the biographer is, in several respects, a very different one from that of the scientific historian. Indeed, it may be affirmed with some shadow of truth that the best biography belongs to the domain of imaginative literature. For to be perfectly successful the biographer must make a hero of his subject; in other words, he must, as an artist, idealise without destroying the features he endeavours to portray. Too often he is a mere ordinary photographer who removes wrinkles and smooths over defects, and thereby produces a picture, recognisable indeed, but of a man in unnatural pose, and ill at ease in holiday garments. Again, the true artist does not crowd his canvas too much, nor does he labour the details of his picture too diligently; we are not tempted to look through our magnifying glasses at particular parts of it, to our loss of the effect of the whole. Finally, he must write from personal knowledge, and with the warmth of personal affection; but he must not allow his feelings to outrun his discretion, or permit his devotion to blind him to the fact that his hero shared the limitations of ordinary humanity. It is just to say that Prof. Thompson passes these tests with a fair measure of success. His biography is well and sympathetically written, it affords a vivid, and, on the whole, a true picture of Lord Kelvin as a student of science, as a university teacher, as an engineer and man of affairs, and as the colleague and friend of a large circle of those devoted to science. If here and there—for example in the account of the latter part of Lord Kelvin's student career and of the proceedings at the Kelvin jubilee—the detail is worked with too microscopic minuteness, the lines are generally bold enough to show the man and his work in fair proportion, and to leave the reader with a feeling of contentment with the manner in which the story of a great life has been told and its achievements recounted.

The task of the scientific historian has already been attempted by Larmor, who has framed an estimate of Lord Kelvin's work such as hardly anyone else could have composed at the present time. But that work will not be seen in its true perspective until some interval of time has elapsed; its full effect on the progress of science cannot until then be traced in detail in the complicated web of scientific fact and theory which so many artists have woven, each interpreting the part of nature's design which lay before his eyes.

The sketch of Prof. James Thomson, Lord Kelvin's father, and of college life in Belfast and Glasgow in the second, third, and fourth decades of the nineteenth century, is somewhat more meagre than it might have been, perhaps; and a little later, when the professor of mathematics appears again, the picture seems a little out of focus. Tales of his efficiency, and of the respect and admiration with which his students regarded him as a teacher, are still current among the few Glasgow graduates who remember the old college as it was in those days, at the beginning of the last quarter of a century of its existence. But no doubt many of the readers of Prof. Thompson's book, like the present writer, have come to it fresh from the perusal of the charming account of the family life of the Thomsons contained in Miss Agnes King's recently published "Lord Kelvin's Early Home"—the reminiscences of Mrs. King, Lord Kelvin's eldest sister—a narrative which, Prof. Thompson tells us, he has purposely refrained from trenching upon.

Prof. James Thomson's oral examinations are still spoken of as stimulating and instructive, and his example was followed with success in Aberdeen by David Thomson, who went there to be professor of natural philosophy after teaching Dr. Meikleham's classes during the years that preceded William Thomson's return from Cambridge. But the power of effective oral examination, like that of maintaining order without effort, is the result of a certain almost indefinable personal quality which many highly gifted men do not possess. The advent of Dr. James Thomson put an end at once to the pea-shooting and other antics in which the students of mathematics had previously indulged; and his personality impressed itself in other ways on university discipline and the conduct of university affairs, through his influence as a member of the Faculty, which, not the Senatus, was then the administrative governing body. In later days the respect which the students felt for William Thomson's scientific eminence, and the controlling force of his temperament, combined to preserve order in his presence and prevent the most daring from taking liberties. His oral examinations, however, were rather an occasion for digressions, which, though highly interesting and instructive in themselves, were not always such as to recall and elucidate the topics dealt with in the previous lecture.

The old college, Prof. Thompson says, was surrounded with horrible slums, and no doubt its environment was sufficiently wretched. This should not be misunderstood. Things were not always so bad in that part of the city, and at the present time, thanks to the Glasgow City Improvement Trust, the conditions of life in the east end have been greatly improved. In the 'thirties and 'forties, when the Thomsons lived in the residential court of the college, the old order of things was passing away. Bailie Nicol Jarvie no longer lived over his counting-house, and the tobacco lords and other wealthy merchants, grown distrustful of the comforts of the Saltmarket, were migrating from Virginia Street to comfortable villas and self-contained houses in the west end, where in a freer air and more healthful surroundings they lived a not much less frugal life. The birth and development of engineering established factories on the Clyde, and brought labourers and mechanics from all quarters. The lanes of the east end were transformed, from places not very different from those which abut against

some of the colleges of Oxford and Cambridge, to rookeries of the worst description. The University had either to await the amelioration of these surroundings, which came later, or leave its beautiful old quadrangles to seek a new home where no such environment existed. Since its establishment on Gilmorehill, it has found the growth of engineering science react enormously on the study of natural philosophy; and now a great new Natural Philosophy Institute and the James Watt Engineering Laboratories exist together, within hearing of the clang of hammers in the great practical laboratories of the Clyde, with which, by their students and the practical problems which continually arise for solution, they are kept constantly in touch. The opening of this institute and of other new buildings by the Prince of Wales on April 23, 1907, was the last public ceremony at which Lord Kelvin presided as Chancellor of the University. The conferring of honorary degrees on the Prince and Princess, which was only one of the incidents of the ceremony, is mentioned by Prof. Thompson; but the real occasion of the visit, directly connected though it was with Lord Kelvin's own work in the University, has somehow escaped his attention.

A full account is given of Lord Kelvin's undergraduate career at Cambridge, and of the visit to Paris which followed it. By that visit, which he made at the suggestion of his father, and with introductions obtained by him, the young mathematician benefited in many ways. He made the acquaintance of Cauchy, Chasles, Liouville, Sturm, and Regnault, and besides studying French—and the cornopean—under Parisian teachers, devoted himself to practical physical work under Regnault, who was perhaps the greatest experimentalist of the century. He received no systematic instruction in experimenting—there was then no provision for such instruction, nor for long after was any provided at any university—but he was present to work the air-pump or to hold a tube, or to stir a calorimeter when told to do so, and thus learned something of the technique of physical manipulation. It must be admitted that he never became himself an expert at such work; and his natural impetuosity in later years, when the irons he kept in the fire were almost innumerable, made his presence in the laboratory a source of perturbations which seriously interfered with the systematic progress of research. Thus there was just a shade of truth in the legend—written on the blackboard by a laboratory student when the knighthood after the laying of the 1866 Atlantic cable was announced—"The (k)night cometh when no man can work"!

The story of his election to the chair of natural philosophy in 1846 is told in detail, and it is interesting to read the principal testimonials presented by Thomson, which have been printed from a complete set in the possession of Dr. Hutchison, of Glasgow. There can be no doubt that he had already impressed all the scientific men whom he had met with his extraordinary ability and promise, and all who support his candidature—including MM. Regnault and Liouville, and Hopkins, Fuller, Leslie Ellis, and De Morgan, predict for him a distinguished future as an investigator. In an appendix to chapter v. (the subject of which is "The Young Professor") is printed the famous introductory address which was annually brought out to be read at the first meeting of the natural philosophy class for the session, but which was invariably departed from within the first three or four minutes, and laid aside to be taken up again only after the lapse of another year. It was a matter for regret that it was not read through each year—it *was* read through in 1846, in much less than the allotted time, and Thomson was so disconcerted that he could find nothing to go on with!—for its language is simple and yet dignified, and well fitted to impress the minds of youthful students beginning the study of natural science. In this address he distinguishes between what he calls "mental history" and "mental philosophy," and between "natural history" and "natural philosophy." He says that

"What may by the analogy of terms be called *mental history,* that is to say, a combination of personal experience and a knowledge of men and of manners, with the study of politics and history, leads us to reason upon the abstract properties of mind, and to investigate that system of general laws on which *mental philosophy* is founded. So in the study of external nature, the first stage is the description and classification of facts observed with reference to the various kinds of matter of which the properties are to be investigated; and this is the legitimate work of *Natural History.* The establishment of general laws in any province of the material world, by induction from the facts collected in natural history, may with like propriety be called *Natural Philosophy.*"

Thus the observations, and their comparison and classification, which led to Kepler's laws, belong to the "natural history" of celestial mechanics; Newton's deductions from Kepler's laws, and the theory of universal gravitation, which account for all the motions of the planets, belong to the "natural philosophy" of the subject. The fundamental subject of natural philosophy is said to be dynamics, or the science of force, and it is interesting to find the importance of this foundation insisted upon for all the principal divisions of physics. Referring to three of these—heat, electricity and magnetism, he says:—

"Our knowledge of these branches of the science is not so far advanced as to enable us to reduce all the various phenomena to a few simple laws from which, as in mechanics, by means of mathematical reasoning, every particular result may be obtained; but observation and experiment are the principal means by which our knowledge in this department may be enlarged. Hence what is called the experimental or physical course includes these three subjects; while the more perfect sciences of mechanics [here he means "dynamics"; "mechanics" he always defined as the science of machines] and optics, being really mathematical subjects, form a distinct division of the studies prescribed by the University for the complete course of Natural Philosophy."

Thomson does not seem to have dwelt on the deductive processes of mathematical physics in his address, though these are quite as important as the induction with which they must be combined. The deductive process by which Adams and Leverrier made

out the place of the planet Neptune from the perturbations of Uranus gave a result which, when found to agree with observation, was generally regarded as affording a much more forcible proof of the truth of the gravitational theory than all the induction which preceded it, and the same thing may be said of results in other departments of physics, which illustrate the *predictive* value of a true theory. A reference to Adams and Leverrier, and the discovery of Neptune, was made in the address, but after 1862 it was omitted by the advice of Prof. Tait, who thought that the subject of Neptune had been "ridden to death."

The provinces of heat, electricity and magnetism, which are referred to in the introductory address as lying in great measure outside the scope of dynamics, it was Thomson's destiny to bring under the sway of the science of forces. He is already, when in Paris, meditating on the results set forth in Gauss's great memoir on attracting and repelling forces varying inversely as the square of the distance, and noticing how the general theorems there given lead to conclusions which were afterwards expressed in the language of the theory of energy. The letter (quoted on p. 130) is interesting in this connection and in some others.

"April 8, 1845. To-day, in the laboratory (of Physique at the Coll. de France, M. Regnault, Prof.), I got the idea which gives the mechanical effect necessary to produce any given amount of free electricity, on a conducting or non-conducting body. If m is any electrical element, v the potential of the whole system upon it, the mechanical effect necessary to produce the distribution is Σmv. . . . Also the theorem of Gauss that Σmv is a mimim. when v is const., shows how the double int^{l} which occurs when we wish to express the action directly, may be transformed into the diff.-co. of a simple int^{l} taken with reference to the distance between the two spheres. . . . This has confirmed my resolution to commence experimental researches, if ever I make any, with an investigation of the absolute force of statical electricity. As yet each experimenter has only compared intensities by the dev^{ns} of their electrometer."

Here we have the train of ideas in progress which led, no doubt, to some of the series of papers on the mathematical theory of electricity which were published later in the *Cambridge and Dublin Mathematical Journal*. But what is still more particularly to be remarked is the determination to measure forces in absolute units. In the discussions of Lord Kelvin's work which have appeared in print, hardly sufficient importance has been attached to the part which Thomson played in the working-out of the scheme of absolute measurements the beginnings of which were made by W. Weber and Gauss. Perhaps, as he confessed later in one of his addresses, he never succeeded in getting the capacities of the leyden jars in his laboratory expressed exactly in absolute units, but it became possible to obtain a fair estimate of these capacities, and to measure, also in absolute units, by means of the beautiful electrometers which he afterwards made, the potentials to which the jars were charged, and therefore to say approximately, in ergs, how much energy was stored up in a particular jar when charged to the measured potential. Each experimenter, he says, expressed his results in terms of the deflections of his own electrometer: not merely was that the case, but currents were measured by each experimenter in divisions on his own galvanometer, and the insulation resistance of a cable at one time could only be compared with its value at another time by using the same instruments as before and reproducing exactly the former conditions. All this had to be swept away and an absolute system substituted when Atlantic cables began to be laid; but an enormous amount of exceedingly valuable work, both theoretical and experimental, had to be done ere a proper system could be elaborated. No small amount of this was accomplished by Thomson and his volunteer laboratory corps at Glasgow, in the "coal hole at the old college," as some members of that corps have since described the famous "first laboratory for students." Then the toil which the members of the British Association Committee undertook in working out, perfecting, and realising the system of units! It was work which did not attract public attention or strike the public fancy; and yet hardly anything else has done more to render possible practical applications of electricity in all their modern ramifications.

In the early 'fifties came the papers on the theory of heat. The account of Carnot's theory of the motive power of heat, with its determination of Carnot's function from Regnault's experiments on steam, valuable as it was, seems to have led Thomson's thoughts into a kind of groove, from which, when Joule's proof that heat and work were equivalent was published, he had some difficulty in escaping, and which involved him in considerable perplexity. It is, as Prof. Thompson says, entirely to the credit of Clausius that he saw clearly at once the full force of Joule's discovery, and accepted implicitly the first law of thermodynamics to which that discovery pointed. After that the necessary modification of Carnot's theory followed immediately, and Carnot's notion of a cycle of operations enabled the whole of the immediate consequences of the true dynamical theory to be worked out. A little later, but independently, Thomson also arrived at the true theory, and by an "axiom," or rather postulate, very differently expressed from that employed by Clausius, but on the whole equivalent, showed that the efficiency of all ideal thermodynamic engines, no matter what their working substances were composed of, had the same value. This in Thomson's hands led afterwards to his definition of absolute temperature, a conception which Prof. Tait used to insist, in the pages of NATURE and elsewhere, was of the most enormous importance, and ought to be set forth at the outset in every treatise on the subject.

Thomson's great paper, followed up as it was by developments and applications of the theory in his later writings, was destined to exert a profound influence on the study of thermodynamics both in this country and abroad. This result was in part due to the peculiarities of his treatment of the subject, which were characteristic of his practical genius.

The object of the memoir is first clearly announced, then the process and its results are unfolded, with a reference at every principal step to the physical meaning of the operation performed and the result obtained; and in every part the process adopted is preceded by a carefully worded statement of the assumptions made, and the presuppositions involved. Clausius, on the other hand, and with him almost every Continental writer, begins by referring to an undefined substance called a "perfect gas," and by means of that substance absolute temperature is defined as R/pv, where R is a constant and p and v are respectively the pressure and volume of a given mass of the gas. Thomson obtained his scale of temperature by means of an ideal engine; and then came the comparison of his scale with that of the air thermometer, by means of his porous plug experiment, which he carried out in collaboration with Joule, in the famous series of experiments on the thermal effects of fluids in motion. This experiment falls at once into clear relation to the whole theory in Thomson's sequence of ideas; this is hardly the case in the other mode of treating the subject.

The earlier papers on heat were all communicated to the Royal Society of Edinburgh, of which Thomson became a fellow in 1847. Of this society he was Keith medallist in 1864, and one of the chief grounds for the presentation of the medal was the discovery of the theorem of minimum energy of a system of connected particles, started by impulses applied at specified points and subject to the condition that the velocities of these points have specified values. This theorem is stated by Prof. Thompson on p. 1141, with rather less than sufficient caution; for if the condition be that the *impulses* applied at the specified points are also specified the motion is one of maximum energy. The far-reaching scope of this theorem is now much better understood than it used to be; for example, by analogy, certain theorems of electricity may be regarded as particular cases of it. The whole subject of these general dynamical theorems has been discussed by Lord Rayleigh in his "Theory of Sound."

The appointment of Tait to the chair of natural philosophy in Edinburgh led to the literary partnership which had as its result the publication in 1867 of the first volume of the "Treatise on Natural Philosophy," and in 1873 of the companion volume, "The Elements of Natural Philosophy." It is matter of keen regret that the second volume at least of the treatise was not forthcoming. For continually in his lectures in 1874, and for some years later, Thomson referred to the discussion of properties of matter which would be contained in that volume, and references to it are frequent in vol. i. If that chapter had been given to the world the treatises on electricity, sound, and hydrodynamics, which we owe to Maxwell, Lord Rayleigh, and Lamb, might well console us for the abandonment of the original scheme. But, as it is, all the old Glasgow students of natural philosophy, who have kept up the study of the subject, will ever regret the loss of the promised chapter, of which they obtained now and then glimpses, when Thomson referred, for example, to the difficulties of the elastic solid theory of the æther, and showed that similar difficulties arose when we attempted to explain the properties of cobblers' wax!

A good idea of Tait's breezy and energetic style of work will be obtained from the letters printed at p. 453, and elsewhere. He was a man of the most kindly feeling and disposition, though the native force of his character and intellect made him a formidable opponent and a severe critic and controversialist. His famous lecture on force will never be forgotten by those who heard it in the Kibble Palace, in Glasgow, in 1876; only a faint idea of it can be obtained by reading his "Recent Advances in Physical Science." He was orderly and methodical; his statements, whether oral or written, were brief and precise, and his lectures were commended by all his students for their unfailing experimental illustrations and the clearness of their expositions.

Thomson could also be clear and precise, nobody more so; but in his popular discourses he was always so preoccupied, and every thought so inevitably suggested new and interesting relations of things, that all his hearers, except a very few, quickly gave up the attempt to follow his lecture, and settled down to listen in admiration and amazement. The writer will never forget the discourse on "Isoperimetrical Problems" which Lord Kelvin delivered at the Royal Institution in May, 1893. The half-humorous picture of the wounded Horatius Cocles limping after the plough, and drawing his furrow so as to get the greatest possible area of land within the given length of boundary, brought the problem home to even the most unmathematical dweller in Mayfair who was present; but when the lecturer went on to make Horatius take account at every step of the quality of the soil, so as to place the maximum value of corn land within his boundary, wonder melted into sympathy for the crippled warrior confronted with such a terrible task! It is well known that the Friday evening discourses must begin at nine o'clock and terminate precisely at ten; but this law, which no one else dared to break, Lord Kelvin disregarded, for when ten o'clock came he had just got into his subject, and he went on—with apologies, of course—until nearly eleven! Such were his fire and enthusiasm; and to the few who remained to the end the *tour de force* was amazing. This would never have happened with Tait; the whole matter would have been thought out from beginning to end; all ideas that might have led him from his straight path would have been ruthlessly put aside, and a model of polished and clear exposition presented. As a rule, Thomson's sentences, both written and spoken, were too heavily loaded with saving clauses; as if he considered himself too absolutely committed to a conditional statement, if its limitations were not all given with it in one word-formula.

It is little wonder in some ways that the literary partnership broke down. But the book was, as Prof. Thompson has called it, emphatically an epoch-making one. It called for and brought about a return to Newton in dynamical method; and it pointed out how the neglected *scholium* on Newton's third law contained in substance the theory of energy. Other text-books are more popular; even the "Elements"—

consisting as it did in many places of the large-type statements of the treatise, without the small-type mathematical demonstrations—was too strong meat for the babes of the Glasgow class. The muttered groans of the students, when on Friday Thomson would first ask them to read twenty or thirty pages of the book before Monday, and then turn to McFarlane and tell him to see that questions were set on the part prescribed in the forthcoming Monday morning examination paper, never reached his ear, and with a bland smile, as if he had just prescribed a novel for the week-end, he used to turn to his oral examination and his lecture.

With regard to the somewhat strong remarks, which we find quoted on p. 445, as to the absurdity of causing Thomson to teach elementary physics, it is right to say that in 1846, when he sought and obtained the chair, the plain everyday duty of the professor of natural philosophy was to teach the natural philosophy class, and that, so far as Thomson was concerned, his time, energy, and original power were far from wasted in meeting from day to day his band of students, most of them eager to learn, and many of them willing to help in his researches. There is no doubt whatever that the attempt to teach them gave him inspiration, and from them came, as another important reward, his laboratory corps, who helped him so much. Witness the tribute to the divinity and other students in the Bangor address. Moreover, it does not seem to be generally known that from the early 'seventies onwards Thomson met the ordinary class only twice, and the higher class only once, a week. He would most certainly have been himself the strongest objector to any arrangement that would have cut him off altogether from his ordinary students. The reflection on the University is undeserved.

Prof. Thompson's second volume begins with 1871, in which year Thomson was president of the British Association at its meeting in Edinburgh. During the following fifteen years or so he was at the height of his activity. His Atlantic cable-laying expeditions were over in 1869, and he had purchased the *Lalla Rookh,* and begun the series of yachting excursions and hydromechanical and other experiments at sea which resulted in the compass and sounding machine. A year or two later some further cable-work was undertaken, which occasioned an eventful visit to Madeira; and then came the introduction into navigation of the fully corrected compass and the sounder, which are now in one form or another on board every well-found and properly equipped sea-going vessel. In the 'eighties he delivered the Baltimore lectures, and invented the various standard electrical instruments for exact laboratory and workship measurements. Afterwards, in the 'nineties, came the peerage, the presidency of the Royal Society, and the never-to-be-forgotten jubilee celebration in 1896.

Of Lord Kelvin's cable work, both theoretical and practical, extending from 1857 to 1874, and of his many other practical activities, Prof. Thompson's book contains an admirable account. It is written in such a way that anyone, however non-mathematical or non-physical, can read it with interest and enjoyment. No such person can lay down the second volume without a feeling of amazement that so much achievement in high regions of scientific discovery and invention could be crowded into one life, even though that extended far beyond the Psalmist's three score years and ten. Indeed, the book may do much good by telling the public at large how much it is indebted for its safety in travelling, for telegraphic communication from continent to continent and between the old world and the new, and for many other benefits (to say nothing of the advancement of natural knowledge), to patient investigation carried on by one man and his corps of willing students and assistants.

There are a few corrections here and there that we should like to see made in a new edition, but these are not of any great consequence, and need not be here enumerated. We have come to the end of the space allotted to this review, and only a few points here and there have been touched upon. The thronging memories of the past suggest innumerable topics on which we might dwell. All around are memorials of the great man who has passed away and the work he carried through. But it is better to forbear, and in a last word to commend Prof. Thompson's book to all who care to know something of the life and the victories of a leader of the armies of peace.

A. GRAY.

DYNAMIC ELECTRICITY.

Electricity. By H. M. Hobart. Pp. xix+207. (London: Constable and Co., Ltd., 1909.) Price 6*s*. net.

IN this book the author attempts to impart to the reader a fundamental knowledge of dynamic electricity without using mathematics, or rather without giving mathematical proofs of his statements. He evidently believes in the possibility of such study, for in the preface he says that

"Without any accompanying study of other text-books, almost anyone who is in earnest can make good progress in acquiring a fundamental knowledge of the subject of electricity, by a careful study of the present treatise."

Now this is rather an ambitious statement, but if the author had followed the orthodox method of using mathematics in elucidation of experiment he might have succeeded. He has, however, deliberately discarded the use of the most efficient tool we have in the interpretation of experimental results, and thus the task of the reader is made more difficult, and not more easy, as he hoped to make it. The author cannot do entirely without mathematics, or at least without expressing certain relations by mathematical formulæ, but he gives these without showing how they are obtained, merely as statements without proof. Here are a few examples: on p. 59 we are told that a circular conductor 1 cm. long, and carrying 10 amperes, acts on a unit pole in the centre of the circle with a force of 1 dyne. No proof is given for this statement, yet, starting from this, the author develops, also without mathematical proof, the law that the magnetic field round an infinite straight con-